CHEMICAL AND BIOLOGICAL DEFENSE PROGRAM
SBIR 13.1 Proposal Submission

General Information

In response to Congressional interest in the readiness and effectiveness of U.S. Nuclear, Biological and Chemical (NBC) warfare defenses, Title XVII of the National Defense Authorization Act for Fiscal Year 1994 (Public Law 103-160) required the Department of Defense (DoD) to consolidate management and oversight of the Chemical and Biological Defense (CBD) Program into a single office – Office of the Assistant Secretary of Defense for Nuclear, Chemical and Biological Defense Programs. The Joint Science and Technology Office for Chemical and Biological Defense (JSTO-CBD), Defense Threat Reduction Agency (DTRA) provides the management for the Science and Technology component of the Chemical and Biological Defense Program. Technologies developed under the Small Business Innovation Research (SBIR) Program have the potential to transition to the Joint Program Executive Office for Chemical and Biological Defense (JPEO-CBD) if the appropriate level of technology maturity has been demonstrated. The JSTO-CBD Science & Technology programs and initiatives are improving defensive capabilities against Chemical and Biological Weapons of Mass Destruction. The SBIR portion of the CBD Program is managed by the JSTO-CBD.

The mission of the Chemical and Biological Defense Program is to ensure that the U.S. Military has the capability to operate effectively and decisively in the face of chemical or biological warfare threats at home or abroad. Numerously factors continually influence the program and its technology development priorities, including planning for warfighting support to asymmetrical threats, the evolving geopolitical environment, development of new threat materials, the threat of global proliferation of chemical and biological weapons, and available DoD resources. Improved defensive capabilities are essential in order to minimize the impact of such weapons. The U.S. military requires the finest state-of-the-art equipment and instrumentation available that permits our warfighters to detect to warn and avoid contamination, if possible -- and to be able to sustain operations in a potentially contaminated environment through protection and decontamination. Further information regarding the DoD Joint Chemical and Biological Defense Program is available at the DoD Counter-proliferation and Chemical Biological Defense homepage at http://www.acq.osd.mil/cp.

The overall objective of the CBD SBIR Program is to improve the transition or transfer of innovative Chem-Bio technologies to the end user – the warfighter – in addition to commercializing technologies within the private sector for mutual benefit. The CBD SBIR Program targets those technology efforts that maximize a strong defensive posture in a biological or chemical environment using passive and active means as deterrents. These technologies include chemical and biological detection for both point and stand-off capabilities; individual and collective protection; hazard mitigation (decontamination); information systems technology to include but not limited to modeling and simulation and operational effects & mitigation; medical pre-treatments (e.g., vaccine development and delivery); medical diagnostics & disease surveillance; and medical therapeutics (chemical countermeasures and biological countermeasures).

Submitting Your Phase I CBD SBIR Proposal

Your entire proposal submission (consisting of a Proposal Cover Sheet, the Technical Volume, Cost Volume, and Company Commercialization Report) must be submitted electronically through the DoD SBIR/STTR Proposal Submission system located at www.dodsbir.net/submission. A hardcopy is NOT required and will not be accepted by the Chemical and Biological Defense SBIR Program. Hand or electronic signature on the proposal is also NOT required.

The Proposal Technical Volume must be 20 pages or less in length. The Cover Sheet, Cost Volume and Company Commercialization Report do not count against the 20-page Proposal Technical Volume page limit. Pages in excess of this length will not be evaluated and will not be considered for review. The proposal must not contain any type smaller than 10-point font size (except as legend on reduced drawings, but not tables).

You must prepare a Company Commercialization Report through the Proposal Submission site and it will be included with your electronic submission; however, the Company Commercialization Report does not count against the proposal page limit. Update your commercialization information if you have not done so in the past year. Note that improper handling of the Commercialization Report may result in the proposal being substantially delayed and that information provided may have a direct impact on the review of the proposal. Refer to Section 5.4.e of this program solicitation for detailed instructions on the Company Commercialization Report.

If your proposal is selected for award, the technical abstract and discussion of anticipated benefits will be publicly released on the Internet; therefore, do not include proprietary or classified information in these sections. Note also that the DoD Web site contains timely information on firm, award, and abstract data for all DoD SBIR Phase I and II awards archived for several years. This information can be viewed on the DoD SBIR/STTR Web site at: http://www.acq.osd.mil/osbp/sbir/.

The CBD SBIR Program uses a Phase I Option to enhance the Phase I to Phase II transition process; the Phase I option may be exercised to fund interim Phase II activities while a Phase II contract is being negotiated if selected for a Phase II award. The maximum dollar amount for a Phase I proof-of-concept/feasibility study is $100,000. The Phase I Option, which **must** be proposed as part of the Phase I proposal, covers activities over a period of up to three months and at a cost not to exceed $50,000. All proposed Phase I Options must be fully costed and should describe appropriate initial Phase II activities, which would lead, in the event of a Phase II award, to the successful demonstration of a product or technology. **The CBD SBIR Program will not accept Phase I proposals which exceed $100,000 for the Phase I effort and $50,000 for the Phase I Option effort**. Only those Phase I efforts selected for Phase II awards through the CBD SBIR Program's competitive process will be eligible to exercise the Phase I Option. To maintain the total cost for SBIR Phase I and Phase II activities at a limit of $1,150,000, the total funding amount available for Phase II activities from a resulting Phase II contract will be $1,000,000.

Companies submitting a Phase I proposal under this solicitation must complete the Cost Volume using the on-line form, within a total cost of $100,000 over a period of up to six months (plus up to $50,000 for the Phase I Option over a period of up to three months). Phase I and Phase I Option costs must be shown separately.

Selection of Phase I proposals will be based upon the evaluation criteria discussed in Section 6.0 of this program solicitation. The CBD SBIR Program reserves the right to limit awards under any topic, and only those proposals of superior scientific and technical quality in the judgment of the technical evaluation team will be funded.

Proposals not conforming to the terms of this solicitation, and unsolicited proposals, will not be considered. Awards are subject to the availability of funding and successful completion of contract negotiations.

CBD Program Phase II Proposal Guidelines

Phase II is the demonstration of the technology that was found feasible in Phase I. The Reauthorization of the SBIR/STTR Program (see Note 1) has resulted in significant changes to the Phase II proposal submission process. Phase I awardees may submit a Phase II proposal without invitation; however, it is strongly encouraged that a Phase II proposal not be submitted until sufficient Phase I progress can be evaluated and assessed based on results of the Phase I proof-of-concept/feasibility study Work Plan and at a recommended five months from date of contract award. **All Phase II proposal submissions must be submitted electronically through the DoD SBIR/STTR Proposal Submission system at www.dodsbir.net/submission.** After Phase I contract award has been made, the CBD SBIR Program Management Office will provide all Phase I awardees with additional information regarding the proposal submission process including key dates.

All proposers are required to develop and submit a commercialization plan describing feasible approaches for marketing the developed technology. Proposers are required to submit a budget for the entire 24 month Phase II period. During contract negotiation, the Contracting Officer may require a Cost Volume for a base year and an option year; thus, proposers are advised to be aware of this possibility. These costs must be submitted using the Cost Volume format (accessible electronically on the DoD SBIR submission site), and may be presented side-by-side on a single Cost Volume sheet. The total proposed amount should be indicated on the Proposal Cover Sheet as the Proposed Cost. At the Contracting Officer's discretion, Phase II projects may be evaluated for technical progress prior to the end of the base year, prior to extending funding for the option year.

The CBD SBIR Program is committed to minimizing the funding gap between Phase I and Phase II activities. All CBD SBIR Phase II proposals will receive timely reviews and be eligible for interim funding (refer above for information regarding the Phase I Option). The CBD SBIR Program typically funds a cost plus fixed fee Phase II award, but may award a firm fixed price contract at the discretion of the Contracting Officer.

Key Dates

13.1 Solicitation Pre-Release	16 November 2012 – 16 December 2012
13.1 Solicitation Open/Close	17 December 2012 – 16 January 2013
Phase I Evaluations	January - March 2013
Phase I Selections	April 2013
Phase I Awards	May 2013 (see Note 2)
Phase II Proposal Submission	Recommend proposal submission no earlier than approximately five Months from date of Phase I contract award. Additional instructions regarding Phase II proposal submission process including key dates will be provided to Phase I awardees after Phase I contract award.

CBD SBIR PROPOSAL CHECKLIST

This is a Checklist of Requirements for your proposal. Please review the checklist carefully to ensure that your proposal meets the CBD SBIR requirements. **Failure to meet these requirements will result in your proposal not being evaluated or considered for award**.

_____ 1. The Proposal Cover Sheet along with the Technical Volume, Cost Volume, and Company Commercialization Report were submitted via the Internet using the DoD's SBIR/STTR Proposal Submission Web site at http://www.dodsbir.net/submission.

_____ 2. The proposal cost adheres to the CBD SBIR Program criteria specified.

_____ 3. The proposal is limited to only **ONE** solicitation topic. All required documentation within the proposal references the same topic number.

_____ 4. The Project Abstract and other content provided on the Proposal Cover Sheet does not contain any proprietary or classified information and is limited to the space provided.

_____ 5. The Technical Volume of the proposal, including the Option (if applicable), includes the items identified in Section 5.3.c of this program solicitation.

_____ 6. The Proposal Technical Volume must be 20 pages or less in length. The Cover Sheet, Cost Volume and Company Commercialization Report do not count against the 20-page Proposal Technical Volume page limit. Pages in excess of this length will not be evaluated and will not be considered for review.

_____ 7. The Company Commercialization Report is submitted online in accordance with Section 5.4.e. This report is required even if the company has not received any SBIR funding

_____ 8. The proposal must not contain any type smaller than 10-point font size (except as legend on reduced drawings, but not tables).

(Note 1) On December 31, 2011, the President of the United States signed into law the National Defense Authorization Act for Fiscal Year 2012 (Defense Reauthorization Act), Public Law 112–81. Section 5001, Division E, of the Defense Reauthorization Act contains the SBIR/STTR Reauthorization Act of 2011 (SBIR/STTR Reauthorization Act), which extends both the SBIR and STTR Programs through September 30, 2017.

(Note 2) Subject to the Congressional Budget process.

CBD SBIR 13.1 Topic Index

CBD13-101	Responsive Sequestration Coatings
CBD13-102	Global Spatiotemporal Disease Surveillance System
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CBD13-104	AOTF-based Spectral Imaging for Enhanced Stand-off Chemical Detection
CBD13-105	Focal Plane Array for Passive Standoff Chemical Detection Based on Colloidal Quantum Dot Technology
CBD13-106	Next-Generation Drug Delivery Technology for Future CBT Antidotes
CBD13-107	Novel physiological depot formulations for long-term butyrylcholinesterase delivery
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CBD13-109	Closures with Hermetic Sealing for Chem Bio Protective Garments
CBD13-110	Self-Healing Shape Memory Polymer Coatings for Chemical/Biological Protective Clothing

CBD SBIR 13.1 Topic Descriptions

CBD13-101 TITLE: Responsive Sequestration Coatings

TECHNOLOGY AREAS: Chemical/Bio Defense, Materials/Processes

OBJECTIVE: Develop responsive spreadable coatings that undergo a change in state upon exposures to environmental stimulus including chemical vapors and/or chemical or biological aerosols. The response should help to mitigate the associated contamination through driving disclosure, sequestration, and/or detoxification.

DESCRIPTION: Coatings are typically used to improve/protect its underlying surface from the environment and blend in with its surroundings. The US DoD employs coatings in a wide variety of applications ranging from corrosion prevention to radar absorption. More recently, sequestration coatings for radioactive materials have been developed and evaluated. A standard for such a coating was put forth by the US EPA that references several important characteristics including the capacity to physically and chemically bind dispersible radioactive contamination; be removable during subsequent decontamination and recovery operations; act as a decontamination agent and withstand a degree of mechanical abrasion, weather effects, and environmental conditions among others.

A similarly purposed coating for chemical contamination is desired. The coating shall be deployed after contamination is deposited on a surface and should offer an immediate barrier to contact and vapor hazards resulting from encapsulated contamination. Ideally, the coating can be applied as a liquid or spray-on gel. The coating should release no volatile solvents (VOCs), including water, during application, curing or treatment (solvent evaporation may release toxic agent into air). The coating shall also entrain the surface contamination, protecting the underlying surface from effects of the contamination and rendering it removable when the coating is removed in the future. The coating must be able to be applied to surfaces with heavy chemical loading (10 g/m2) without disruption of performance degradation of the sequestration properties. Ideally, in the future, the coating would both indicate the location of contamination within the coating and also drive its detoxification. The sequestration coating will be robust but also easily removed from the substrate such that upon removal, the underling surface will be thoroughly decontaminated but not damaged. The coating should remove/neutralize 99% of the residual chemical warfare agent challenge within 100 hours after application under ambient operating conditions.

Existing performance data with chemical warfare simulants or live agents will be valuable in evaluating submissions.

PHASE I: Demonstrate the ability to sequester chemical agents within an applied coating material, both removing them from an underlying surface and neutralizing the agents while keeping them from breaking through the coatings as contact or vapor hazards. A successful Phase 1 effort should conclude with a demonstration on at least three chemical agent simulants. Demonstration on one live chemical agent using an approved surety lab is desirable but not required.

PHASE II: Based on the results of the preliminary testing of Phase I, perform a thorough assessment of the coating's capacity to handle different doses of simulants and agents that were applied to relevant surfaces in different forms (fine mist, small droplets, large droplets). Phase II should further demonstrate disclosure / detoxification capabilities of the coating while ensuring that coating removal does not irreparably damage the underlying surface. Phase II should also demonstrate the ability of the coating to indicate the presence of agent under the coating. The successful offerer will also demonstrate that the coating employed is manufacturable at a scale and cost that are conducive to wide area military applications.

PHASE III: Develop a commercial system for application of the coating that can be used throughout the U.S. DoD. The effectiveness of the coating should be fully quantified against live agents in 3rd party tests. Appropriate approval from regulatory agencies, such as the EPA should be sought as necessary for field application of the coating. A likely transition path for the technology is through the Joint Program Executive Office for Chemical and Biological Defense (JPEO-CBD). This technology would also have broad civilian application in hazardous material spill clean up.

REFERENCES:
1. Drake, J. 2009. Sequestration Coating Performance Requirements for Mitigation of Contamination from a Radiological Dispersion Device. Waste Management Symposium WM'09 Conference, March 1 - March 5, 2009, Phoenix, AZ.

2. Test Operations Procedure (TOP) 8-2-061. "Chemical and Biological Decontaminant Testing," 19 November 2002. Available through the National Technical Information Service (www.ntis.gov).

KEYWORDS: coatings, chemical warfare agent

CBD13-102 TITLE: Global Spatiotemporal Disease Surveillance System

TECHNOLOGY AREAS: Chemical/Bio Defense, Biomedical

OBJECTIVE: The objective is to develop a device to collect and analyze biological data to enable real time disease surveillance. The system developed should be small, lightweight, rugged, not require external power for >8 hours, and be able to directly transmit data to a central depository.

DESCRIPTION: Rapid-Diagnostic-Tests (RDTs) are based on antibody-antigen interactions to specifically detect ligands of interest (e.g., bacterial or viral pathogens, toxins, or other biomarkers) (1). There are multiple formats for these tests with lateral flow (hand-held assays), flow through, agglutination, and solid phase (dipstick) formats most common. While the protocols for conducting the tests vary between formats, the end result in most cases is the presence or absence of a colored line for a positive control and another for the test sample. The test line(s) is visually evaluated; a line at the positive control position to indicate a valid result, and the presence or absence of a line at the test location to indicate presence or absence of the ligand. RDTs are used worldwide for diagnostics, disease surveillance, and epidemiology)(2) and are available for many pathogens, including potential biowarfare agents (3, 4). At least one vendor offers a reader (4) to reduce the chance of false negative results by using digital imaging to increase contrast between the line and background. This reader also documents the test result, records the date and time and can directly email the results. The disadvantages of this device are that it is heavy (>2 pounds), has a limited battery life (5 hours), depends on Wi-Fi internet access for communications, and can only read diagnostic strips of a given size and shape. Since RDTs are produced by many vendors and come in a range of sizes and shapes, the latter by itself is a serious limitation. Recent advances in electronic imaging and communications technologies suggest that it is feasible to make universal readers that capture spatiotemporal information, interpret test results, and transmit all the data, raw and interpreted, to a central collection point. At the central collection point the spatiotemporal information and test result could be visualized in an easily comprehensible manner. With many detection units in the field, such a system would enable real-time monitoring of the spread of an epidemic or of chemical or biothreat agents.

PHASE I: Demonstrate proof of concept that a small device can consistently read RDTs produced by a variety of manufacturers (at least 4 different formats) with sensitivity that equals or exceeds that of normal visual detection; that test results can be captured, processed, and accurately (>95%) interpreted on the device; that spatiotemporal data can be collected and linked directly with test results; that data from hundreds of tests can be stored and fully accessible locally; and, complete data sets can be transmitted to a central collection point automatically, or manually if desired.

PHASE II: Develop a prototype device that is cost-effective (<$500), light weight (<8 oz), rugged and can be used in the field to read and interpret the major RDTs that are commercially available. The device must work continuously for >8 hours without external power sources. It should recognize the inserted RDT (manufacturer, test type) and prevent operation unless the RDT is inserted properly. The device should be simple to use and require minimal training. After the RDT is read, the device should store the data and when possible, automatically transmit test results (raw and interpreted) and spatiotemporal data to one or more central collection points that can be set by the user. If unable to transmit immediately, the data should remain stored on the device until transmission is possible. The field device should seamlessly communicate with the central collection point (e.g., server) without user input. The device should not require internet access to transmit data, although ability to transmit via the

internet or the presence of Bluetooth capabilities would be a plus. The target for the data transmission should be specifiable by the user in order to adapt on the fly to local (national) and international data collection procedures/requirements, including the ability to transmit data to more than one receiving point. In addition to full data set transmission, users must have the ability to select "personally identifiable" or "de-identified" for each individual receiving point.

PHASE III: Construct ROC curves and validate the frequencies of false positive and false negative results obtained. Use appropriate methods to minimize these frequencies and improve accuracy. Determine the minimum telecommunication infrastructure requirements needed for basic functionality as well as the maximize storage capacity for a typical device as well as the number of diseases/tests that can currently be evaluated given the parameters of the device and the commercial availability of RDTs at this time.

PHASE III DUAL USE APPLICATIONS: Inexpensive readers with the ability to exceed visual detection limits and to document test results would find extensive use by first responders, in civilian medical facilities, in the public health field, and for point of care diagnostics in remote regions throughout the world.

REFERENCES:
1) http://www2.wpro.who.int/sites/rdt/home.htm

2) http://www.rapid-diagnostics.org/index.htm

3) http://www.tetracore.com

4) http://www.coleparmer.com/Category/Biowarfare_Agent_Detection_Devices_BADD/40362

5)
http://www.southernscientific.co.uk/store/public/application/file//document/Tetracore_BioThreat_Alert_Reader.pdf

KEYWORDS: Disease Surveillance, Point of Care Diagnostics, Epidemiology, Rapid Diagnostic Tests, RDT, Biothreat Agent Detection, RDT Reader, Data Collection

CBD13-103 TITLE: Advanced Real-Time Surface Contamination Sensor

TECHNOLOGY AREAS: Chemical/Bio Defense, Sensors

OBJECTIVE: Demonstrate and deliver a novel, noncontacting, broad area rapid scanning surface contamination sensor to provide threat warning in real time.

DESCRIPTION: The LWIR (long wave infrared) portion of the spectrum possesses absorption, backscatter, and radiation features that can be used with some limited success to detect and identify chemical agents on surfaces. Passive hyperspectral imaging at LWIR is one such approach that uses the sun as the primary illuminator; however, the signal-to-noise ratio (SNR) per pixel is relatively low. On the other hand, a wavelength-agile LWIR laser could provide high SNR per pixel. One possible laser source is the CO2 type which can provide wavelength diversity over approximately 60 lines in the 9.3-10.7 micron band. A laser source of this kind may need to be expanded in its wavelength diversity, possibly by use of isotopic mixtures to achieve perhaps 120 lines, approximating a high intensity continuous broadband illuminator. The laser would have to be made highly divergent in order to illuminate the scene in a single shot. A compact CO2 laser can probably be made powerful enough to cover a relatively large field of view at high intensity for multiple wavelength (active hyperspectral) imaging.

It is likely that fusion of data from an intense laser source with dense wavelength diversity (approaching a continuous source such as the sun) and a passive hyperspectral channel would provide significantly enhanced SNR compared to either channel alone. It may be possible that the laser source could provide the required SNR alone. Advanced detection algorithms would be needed to maximize the likelihood of detection in a single channel, and

then in the combined fusion channel. It will be essential that the algorithms operate in real time, suggesting that they be robust and not overly complex. Recent advances in fast algorithms suggest that this will be possible.

In the case of a combined active and passive sensor, a complication in detecting surface contamination is the presence of the natural background reflection (active) and emission (LWIR passive) from the surface itself. Because of the small signals at contamination levels that must be detected, a detection algorithm using a physics-based radiative transport (RT) model that includes both emission and reflection components from the natural background and contamination would be useful.

The multispectral passive image component of the RT model could lead to a method for estimating both spectral and spatial components for two or more background materials. An adaptation of the methods used for unmixing multiple aerosols from multiple wavelength lidar backscatter data could be useful for the background estimation task. A Kalman filtering approach would provide fast real time processing. Previously developed models for chemical detection with FLIRs may be adaptable to surface reflection and emission for the complete active/passive sensor configuration.

Recent field testing with the ECBC FAL (Frequency Agile Laser) sensor and CO2 TEA (Transversely Excited Atmospheric) laser transmitter has demonstrated that airborne chemical vapors, chemical aerosols, and biological particles can be simultaneously detected. If surface contaminant detection at LWIR proves feasible, then it will be possible to detect a large number of agents in various forms with a single sensor. Passive hyperspectral sensors, cannot detect biological particles or chemical aerosols.

PHASE I: Develop a physics-based model for the combined active/passive sensor under background-only and background plus contamination cases. Using that model, develop an algorithm for estimating the background signal components and develop a prototype detection algorithm that could be generalized in Phase II to a real-time processor. Develop performance and sensor design analysis for a laboratory proof-of-principle surface sensor. Assemble the demonstrator and operate it under direct sunlight to obtain a data base for surface detection at a range not less than 1 m and for at least a two component mixture of interferent and agent simulant. Apply the proof-of-principle algorithms to the data base and demonstrate surface detection with discrimination between the (at least) two mixture components. Based on the initial sensor performance, assemble a detailed roadmap for further development of algorithms and critical sensor components for a compact, real time sensor brassboard to be fabricated, demonstrated, and delivered in the Phase II program.

PHASE II: Use the results of the Phase I effort as a data base to develop detection algorithms that operate in real time and to develop a fieldable brassboard sensor. Fabricate the brassboard sensor and demonstrate that it meets the proposed detection sensitivity goals. Demonstrate the sensor in an external ambient environment under direct sunlight. Deliver the sensor in brassboard form suitable for field testing by the Army. Provide advanced sensor concept analysis to show that a prototype sensor can be built with a volume of not greater than 4 cu. ft. and capable of real-time detection/identification of multiple agents on surfaces.

PHASE III: The novel Advanced Surface Contamination Sensor delivered under this program would be put into field trials to develop a performance data base for all agent targets. The data base would support parallel development of advanced algorithms for simultaneous detection/identification of the specific agent types and for development of integrated sensor operational protocols. The combination of sensor performance data, advanced algorithms, and sensor operation procedures would form the basis for development of a preproduction Advanced Engineering Model for military deployment, civilian homeland defense, and environmental monitoring. Field demonstration of the advanced prototype(s) would provide the basic information for formulation of a development consortium including private industry and the government.

PHASE III DUAL-USE APPLICATIONS: The Advanced Surface Contamination Sensor would fill important roles in rapid threat detection with a noncontact, compact sensor for homeland security and environmental monitoring for which there are presently no adequate solutions.

REFERENCES:

1. R. Warren, S. Osher, and R. Vanderbeek, “Multiple aerosol unmixing using the split Bregman algorithm”, to appear in Trans. Geoscience and Remote Sensing.

2. M. Althouse and C. Cheng, “Chemical vapor detection with a multispectral thermal imager”, Optical Engineering, vol. 30, no. 11, pp. 1725-1733 (1991).

3. R. Warren, R. Vanderbeek, and J. Ahl, "Online estimation of vapor path-integrated concentration and absorptivity using multi-wavelength differential absorption lidar", Applied Optics, Vol. 46, No. 31, pp 7579-7586, 2007.

4. R. Warren, R. Vanderbeek, A. Ben-David, and J. Ahl "Simultaneous estimation of aerosol cloud concentration and spectral backscatter from multiple-wavelength lidar data", Applied optics, Vol. 47, No. 24, pp 4309-4320, 2008

5. Warren, R. Vanderbeek, and J. Ahl, "Estimation and discrimination of aerosols using multiple-wavelength LWIR lidar, "R. SPIE Conference 7665, Chemical, Biological, Radiological, Nuclear, and Explosives Sensing XI, Orlando, FL, April 2010

6. R. Vanderbeek, R. Warren, and J. Ahl, “LWIR Differential Scattering Discrimination of Bio-Aerosols” Seventh Joint Conference on Standoff Detection for Chemical and Biological Defense, Williamsburg, VA, Oct 23-27 (2006).

7. D. Cohn, J. Fox, and C. Swim, "Frequency agile CO2 laser and chemical sensor", IRIS Active Sensor Conference, Monterey, CA, Nov. 1993.

KEYWORDS: CB sensor, proximal sensor, optical sensor, realtime sensor

CBD13-104 TITLE: AOTF-based Spectral Imaging for Enhanced Stand-off Chemical Detection

TECHNOLOGY AREAS: Chemical/Bio Defense, Sensors

OBJECTIVE: Build an AOTF Imaging System for Enhanced Standoff Chemical Detection in the Long-wave Infrared Region.

DESCRIPTION: Acousto-optics can be defined as the study of the interactions between sound waves and light waves. In particular it is the study of diffraction of light by ultrasound or sound in general. Acousto-optic effects are usually based on the change of the refractive index of a medium due to the presence of sound waves. The sound waves can produce an effective refractive index grating in the material which influences the propagation of the light beam. There is a growing interest in acousto-optical devices for the deflection, modulation, signal processing and frequency shifting of light beams. Recent progress in crystal growth and high frequency piezoelectric transducers have enabled this technology.

The Chemical and Biological Defense community has the need for better methods of standoff detection of chemical and biological agents. Infrared absorption spectroscopy has proven to be a very useful tool in the detection and identification of airborne chemicals and aerosols. Pattern recognition is used to compare the infrared spectrum of library molecules against the infrared spectra of airborne contaminants. In particular, chemical warfare agents and Toxic Industrial Chemicals (TICs) have distinctive absorption lines in the infrared region. Infrared spectroscopy has been used to detect chemicals at very low concentrations. Infrared spectroscopy also holds the promise of low false alarm rates due to the spectral pattern matching over a large number of spectral bins.

The size, weight, and power requirements of current infrared spectrometers have limited their utility in field environments. Chemical agent infrared absorption/emission is largely confined to the 8 to 12 micron region of the EM spectrum. Tunable filters such as Acousto-Optic Tunable Filters (AOTF) are just becoming available in this wavelength region. In an AOTF-based sensor, selected wavelengths of light can be deflected onto a focal-plane-array, providing spectral imaging capabilities. The resulting imaging system would have a number of advantages over conventional standoff systems. The proposed system would contain no mechanical moving parts, making it inherently rugged and precise. The system could be made compact and thus easily integrated into a variety of

configurations. Inexpensive infrared longwave focal-plane-arrays are now becoming available allowing for low cost imaging capabilities.

AOTF technology also allows for the simultaneous detection of two or more wavelengths of light. This effect could be used to provide better methods of optical pattern matching for standoff chemical/biological detection. Methods of compressed sensing could be utilized to reduce data acquisition times and improve detection probability. AOTF technology may also provide polarameteric imaging capabilities. Current standoff capabilities for aerosol detection and tracking could be significantly enhanced using polarization information.

PHASE I: Develop and design an AOTF-based spectral imager using a longwave infrared focal plane array. Design a lightweight, low-power, inexpensive hyperspectral imaging sensor for wide area standoff detection of chemical agents. The ability to also use the technology to detect biological agents would be advantageous. The spectral region of the sensor should be chosen to interrogate spectral signatures of chemical plumes. Traditionally the 8 to 12 micrometer region of the electromagnetic spectrum has been used for standoff chemical detection. The system should have sufficient spectral and spatial resolution to detect and discriminate chemical agent plumes. The detection and discrimination capabilities of the sensor in this region should be comparable to existing HSI chemical/biological sensors. The goal is to passively detect small chemical plumes (25 meters or smaller) of a chemical agent such as sarin at relevant concentrations (less than 10 ppmv) at a distance of 5 kilometers or more under ambient conditions.

PHASE II: Build and test an AOFT spectral imaging system. Construct a standoff hyperspectral imaging sensor designed for the detection of chemical plumes. Utilize the best methods and technologies for reducing the size and weight of HSI systems while maintaining required sensitivities. Test and characterize the performance of the new HSI sensor. Based on the test results, refine the design of the new standoff chemical imaging sensor.

PHASE III: DUAL USE APPLICATIONS: Further research and development during Phase III efforts will be directed towards a final deployable design, incorporating design modifications based on results from tests conducted during Phase II, and improving engineering/form-factors, equipment hardening, and manufacturability designs to meet U.S. Army CONOPS and end-user requirements. Further, demonstrate the technology's applicability to stand-off detection of chemical and biological threat materials. There are many environmental applications for a small chemical standoff sensor. A rugged, sensitive and flexible chemical detector will benefit the manufacturing community by providing finely tuned monitoring of chemical processes. Also, first responders such as Civil Support Teams (CST) and Fire Departments have a critical need for a rugged, relatively inexpensive but versatile and rugged sensor that can be transported to the field to test for possible contamination by CW agents and other toxic chemicals.

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1. Neelam Gupta, "Investigation of a mercurous chloride acousto-optic cell based on longitudinal acoustic mode", Applied Optics, volume 48, issue 7, pages C151-C158, 2009.

2. I. C. Chang, "Acousto-optic tunable filters", Optical Engineering, volume 20, page 824-829, 1981.

3. N. B. Singh, D. Kahler, D. J. Knuteson, M. Gottlieb, D. Suhre, A. Berghmans, B. Wagner, J. Hedrick, T. Karr, and J. J. Hawkins, "Operational characteristics of a long-wavelength IR multispectral imager based on an acousto-optic tunable filter", Optical Engineering, volume 47, issue 1, page 013201, 2008.

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KEYWORDS: Keywords: hyperspectral imaging, infrared spectroscopy, standoff detection, Acousto-optics, Acousto-Optic Tunable Filter, AOTF

CBD13-105 TITLE: Focal Plane Array for Passive Standoff Chemical Detection Based on Colloidal Quantum Dot Technology

TECHNOLOGY AREAS: Chemical/Bio Defense, Sensors

OBJECTIVE: Develop methods that enable the production of low cost long wavelength infrared (LWIR) focal plane array technology specialized for use with chemical imaging sensors using colloidal quantum dot technology.

DESCRIPTION: The Chemical/Biological Defense community has a need for passive standoff systems that detect and classify areas contaminated with chemical and biological vapors, aerosols, liquids and solids. Recently, hyperspectral imaging systems have shown great promise for the detection, identification, and real time display of chemical vapor and aerosol clouds. However, deployment of hyperspectral technology is limited by the cost, yield, and reliability of the infrared focal plane technology used in these sensors. The infrared focal plane array technology required for passive standoff detection of chemical and biological signatures is significantly different from the technology optimized for thermal imaging. The subdivision of far field spectral radiance into discrete spectral bands requires array technology with higher sensitivity, shorter integration times, and lower noise figures than is typically achieved with un-cooled technology. Similarly, the need for spectral response cutoff ranges in the 10 to 12 micron wavelength range to access important CB and toxic industrial material signatures exceeds the requirements for cooled thermal imaging devices while placing an additional burden on the cryocoolers needed to achieve requisite noise levels. The present topic addresses the need to develop and mature new infrared focal-plane-array technologies, to minimize/eliminate the requirement for cryogenic cooling, and to reduce costs.

II-VI semiconductors have been successfully used for long wavelength infrared (LWIR) hyper spectral imaging within the Chemical/Biological defense community for some time. In particular HgCdTe photodetectors have been used successfully over a large range of wavelengths for chemical sensing. HgCdTe is a mature technology that has seen wide usage. However, HgCdTe fabrication still remains plagued with very low yields and high costs for device quality HgCdTe material. Also, HgCdTe requires cryogenic cooling at LWIR wavelengths. The high cost of HgCdTe and the need for cryogenic cooling have severely limited its application.

Recently II-VI materials have been developed in colloidal quantum dot form. These materials have seen successful application in areas such as LED’s and solar cells. Colloidal quantum dot technology has the advantage of low cost and does not require apitaxial growth on expensive substrates. To date most colloidal quantum dot devices are based on cadmium or zinc chalcogenides and have been used for telecommunications type applications. The goal of this effort is to extend the utility of colloidal quantum dot devices to longer wavelengths in the infrared. This will require the use of II-VI materials with a lower bandgap. Candidates include PbS, PbSe, HgS, and HgTe. Recently infrared

photodetectors have been demonstrated with cutoffs at 7 microns using HgTe colloidal quantum dots. It should be possible to extend this technology to the 8 to 12 micron spectral region for chemical/biological sensing applications.

PHASE I: Examine methods for producing infrared focal plane arrays that are designed for use in standoff chemical and biological sensors based on colloidal quantum dots. Develop reliable fabrication methods for the production colloidal quantum dots. Characterize the new quantum dots and identify a path for practical realization of low-cost, high-performance LWIR focal plane arrays based on this technology. Conduct a study to define the spectral response range, pixel size and format, and noise requirements for focal plane array technology to be used across a range of standoff hyperspectral imaging system technologies. Examine methods to extend the capabilities of II-VI colloidal quantum dot photodetectors into the long wave infrared region (8 to 12 microns). Examine focal plane array (FPA) design constraints and imaging requirements to achieve designs that improve yield and quality while meeting cost and performance targets. Develop a manufacturing improvement plan for the production of the technology that identifies further research and development needed for this effort.

PHASE II: Fabricate prototype focal plane arrays and assess FPA performance at the device level. Explore pathways to manufacture the IR FPA material and devices. Manufacturing development will require safe and reproducible production of large quantities of device quality quantum dots along with subsequent procedures to fabricate and characterize FPAs. Examine FPA formats of interest the chemical biological defense community and develop appropriate manufacturing methods. Develop and implement readout electronics designs required to effectively utilize the focal plane array technology. Explore the packaging of focal plane arrays into an integrated detector assembly for use with a hyperspectral imager and assess the performance of the system. Determine and document improvements in the system.

PHASE III: Further research and development during Phase III efforts will be directed towards refining a final deployable design, incorporating design modifications based on results from tests conducted during Phase II, and improving engineering/form-factors, equipment hardening, and manufacturability designs to meet U.S. Army CONOPS and end-user requirements. The primary barrier to the broader use of hyperspectral technology for remote sensing of hazardous materials has been the technology cost, which is primarily driven by the cost of the focal plane technology. First responders such as civilian support teams, fire departments, and military post-blast reconnaissance teams have a critical need for a rugged and versatile and low cost sensor that can be transported to the field to test for possible CB contamination. This effort will facilitate the transition of the technology to those applications.

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KEYWORDS: Chemical detection, II-IV semiconductor materials, colloidal quantum dots, focal plane array, infrared spectrum.

CBD13-106 TITLE: Next-Generation Drug Delivery Technology for Future CBT Antidotes

TECHNOLOGY AREAS: Chemical/Bio Defense, Biomedical

OBJECTIVE: Develop and demonstrate a drug delivery platform that is compact, lightweight, and robust for field use. This drug injection platform should enable the rapid injection of reconstituted wet-dry formulations in addition to single component wet and multi-component wet formulations, typical of next-generation chemical, biological, and toxin (CBT) antidotes.

DESCRIPTION: The modern Warfighter is experiencing a progressively more complex battlespace. Threats from weapons of mass destruction such as chemical, biological, and toxin (CBT) weapons are increasing, and are more likely to occur with minimal warning to the Warfighter. These threats require the Warfighter to have ready access to state-of-the-art CBT antidotes in delivery systems that are:

- Field-ready, robust & reliable
- Easy & rapid to use
- Environmentally stable
- Compact & lightweight

Next generation antidote compounds are often expensive, chemically complex and lack stability [thermal, oxygen, UV, shear] in solution. Dry antidote formulations represent one successful approach to address those issues of stability. This leads to a need for an injection technology that can store, reconstitute, and inject the antidote formulation rapidly in the field.

Current autoinjectors have met previous needs but have a limited ability to handle next-generation antidotes. Existing nerve agent autoinjectors, for instance, have some of the following limitations:

- Compound specific (not platform based)
- May contain glass or other fragile materials, less than ideal for field deployment
- Large and awkward to carry by or for the Warfighter
- Not optimized for thermal and chemical stability
- Not optimized for next generation antidotes including large molecules, biologically-derived compounds, and other labile materials

Existing autoinjectors incorporate pre-filled syringe technology. While there have been some developments to include polymer or plastic-based materials, current technology often exposes the pharmaceutical product to metals and other materials of construction that accelerate the degradation and/or contamination of the stored pharmaceutical ingredient.

Based upon these challenges to fielding future CBT antidotes, the Department of Defense (DoD) sees a need for an autoinjector technology that provides the Warfighter with a compact, field-ready, cost-effective platform for the long-term storage of any given CBT antidote that does not present a significant logistical burden. This drug injection platform ideally can handle single component wet, multi-component wet, and wet-dry formulations. This drug injection platform would be sized for optimum portability. CBT antidotes, as post-exposure therapies, are envisioned to be either medic carried or in personally carried, self- or buddy administered drug-delivery devices for intramuscular or subcutaneous injection. Administration may or may not be required through personal protective equipment. However, intravenous injection is not suitable for field use.

An example of an innovative technology that may be considered for a future CBT antidote-delivery platform are microelectromechanical (MEMS) systems. MEMS have been used to create complex mechanical and fluidics structures in a small volume using established, low-cost manufacturing techniques.1 These systems have been used to rapidly and accurately detect the presence of target compounds in the environment and in the human body.2,3 These systems are only now being applied to drug delivery systems.4

The goal of this topic is to develop a drug delivery platform capable of being approved by the FDA that will be robust & reliable, easy-to-use for the Warfighter, compact, and lightweight. Ideally, this drug delivery system will be small enough to hang on the Warfighter's ID tags or by its compact size, be readily portable by combat medics.

PHASE I: Key functional technology is proved computationally and, at a minimum, at the bench scale. This could include both mechanical and fluid simulation and/or testing that would support the effectiveness and compact

dimensions of the final autoinjector. Prototyping and testing of systems and subsystems that enable the path to a compact, drug injection platform would be successfully completed using suitable pharmaceutical compounds or simulants of fielded or future CBT antidotes.

PHASE II: The overall device design will be finalized and the prototypes of the drug delivery system manufactured and demonstrated. All of the systems and subsystems in the device will be optimized and documented. The small business firm will show the functionality of the device for the injection of typical liquid, multi-liquid, and/or wet/dry component pharmaceutical systems that are commensurate with fielded or future CBT antidote regimens (i.e., administration by the next-generation delivery technology is suitable to deliver efficacious pharmaceutical levels of a CBT therapy). This testing will show the consistent functionality and field suitability of the resulting autoinjector platform. The small business will demonstrate to the DoD how their device is consistent with FDA guidelines and could be approved for drug injection via the 510(k) route. This phase of work will not include any animal or human testing.

PHASE III: In this phase, any additional changes from customer feedback will be incorporated into the design, and the initial drug to be supplied to the DoD in the injector system will be selected. A detailed data package will be developed for submission to the FDA for approval of the autoinjector platform or the autoinjector platform/drug combination suitable for administration of CBT therapeutics. Once this compact and robust autoinjector platform is approved by the FDA, it could be filled with other pharmaceutical compounds that would benefit civilian markets such as diabetes care, pain management, and large-molecule drug delivery.

PHASE III DUAL USE APPLICATIONS: A compact, easy-to-use, and temperature tolerant autoinjector would serve the commercial market for drug injection. For example, thermally stable vaccines, pre-loaded into the injection platform, could have value to rapidly control outbreaks worldwide and would eliminate the need for intermediate steps to include drug reconstitution and manual mixing, along with the need for a high-value medical professional.

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KEYWORDS: drug delivery, autoinjector, injector, medical countermeasures, platform device, FDA

CBD13-107 TITLE: Novel physiological depot formulations for long-term butyrylcholinesterase delivery

TECHNOLOGY AREAS: Chemical/Bio Defense, Biomedical

OBJECTIVE: A capability is sought to deliver human butyrylcholinesterase (BuChE) into blood circulation from a depot that can be administered intramuscularly or subcutaneously and which can maintain blood BuChE concentrations above 80 micrograms/milliliter for periods exceeding 10 days. The ability to maintain elevated blood BuChE concentrations is an operationally desirable capability that allows for extended prophylactic protection from the effects of organophosphorous agents while minimizing the need for repeated administration.

DESCRIPTION: Elevated BuChE plasma levels confer prophylactic protection from the effects of organophosphorous agents by scavenging these agents in the blood stream before they can reach terminal nerve

synapses. We seek a capability to deliver butyrylcholinesterase into blood circulation in a timed-release manner in order to maintain elevated BuChE concentrations over extended periods of time.

Operational requirements for certain types of missions make it impractical for health care providers to administer repeated intravenous doses of BuChE in order to maintain a sufficiently high plasma concentration to afford protection over the duration of a mission. The ability to deliver and maintain sufficiently high BuChE concentration in the blood without repeated dosing is a capability that would enhance the operational utility of BuChE as a prophylactic, particularly in support of extended-duration missions in areas where health care providers are not available to administer this prophylaxis.

The proposed system must allow for subcutaneous or intramuscular administration of a stable depot that can sustain delivery of butyrylcholinesterase into circulation over the course of at least 10 days. The depot should be able to maintain a BuChE plasma concentration of 80 micrograms/mL over the 10 day period. The proposed solution may be composed of any suitable material(s) to achieve the required performance characteristics. Administration at multiple injection sites is acceptable. Unless otherwise exempted, the proposed design must be informed by requirements for eventual approval under the Food and Drug Administration regulatory pathways for drugs, biologics, or medical devices.

PHASE I: The performer will demonstrate the formulation of BuChE into a depot system that is capable of delivering BuChE at the proper release rate to sustain blood concentrations over the time period specified above. Demonstration using an in vitro model system is acceptable. Modeling and simulation of depot performance to support in vitro or in vivo study design(s) is highly encouraged.

PHASE II: The performer will evaluate performance and conduct early animal trials in an established animal model in collaboration with an entity capable of working with nerve agents and in consultation with the US Army Medical Research Institute of Chemical Defense (USMRICD). Conduct detailed characterization of depot performance in a suitable animal model, demonstrate in vivo efficacy against nerve agent challenge using an established animal model, and conduct toxicology and safety studies required to support an IND, 510(k), or related FDA filing.

PHASE III: The performer or a suitable partner will conduct a Phase 1 clinical trial to establish human safety and obtain pharmacokinetic performance data.

PHASE III DUAL USE APPLICATIONS: Sustained delivery of large molecule therapeutics is an open problem with a large potential market and with direct applicability to dozens of FDA-licensed biologics. Successful completion of all three phases under this solicitation will support small business valuation by confirming technical merit that invites further investment. This award mechanism will bridge the gap between laboratory-scale innovation and entry into a recognized FDA regulatory pathway leading to commercialization.

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KEYWORDS: Drug delivery, depot, timed release, butyrylcholinesterase, chemical, nerve agent, countermeasure

CBD13-108 TITLE: Rapid biodosimetry for accurate assessment of individual radiation exposure levels

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: The development an applicable biodosimeter in order to identify the level of radiation and/or to inform a medical treatment intervention, based on the radiation exposure. The biodosimeter must be accurate, sensitive to multiple levels of radiation, relatively non-invasive, scalable for high throughput, possess the ability to be cleared by the U.S. Food and Drug Administration (FDA), and usable in a contemporary operational environment. The dosimeter technology must diagnose quick reacting markers that allow for triage in a military operational environment within 4 hours of exposure to ionizing radiation within the boundaries of (= 1.0 Gy) with a stated statistical certainty. It is desirable that the biodosimetry device use a well qualified biomarker for absorbed radiation and the device output can be readily interpretable and obtainable.

DESCRIPTION: Identify, evaluate and characterize markers of radiation injury to specific organs and tissues of physiological systems, in order to allow for timely and appropriate triage and administration of medical countermeasures and/or other medical treatments to radiation victims in a military operational environment. Ideal biomarkers are those that arise and are measurable prior to expression of tissue injury and thereby provide a time window for use of medical countermeasures that can mitigate injury. Useful biomarkers should be linked to relevant clinical outcomes such as organ failure, other major morbidity and/or mortality. It is important to develop methods to demonstrate that the change in the biomarker is related to the radiation exposure and not to other non-specific response to other health status, environmental and/or physiological factors.

PHASE I: This phase will identify and justify a suitable biodosimetry tool, demonstrate feasibility, outline a plan with milestones and criteria for successful development and adaptation of the method to a validated model. The radiation biomarker(s) should be measurable in a non-invasive or minimally invasive way, allow for repeated assays over time, be sensitive to incremental changes in radiation exposure, be specific over a wide range of radiation doses and dose-rates, and be equally-reliable for different qualities of radiation (greater than or equal to 1.0 Gy).

Milestones and deliverables for Phase I:

1. On completion of Phase I, the contractor will provide conceptualization, design and feasibility test results of innovative, biodosimetry tools that can function as rapid, reliable, inexpensive and easy-to-use techniques/assays and devices in the military operational environment. The biomarker signal(s) should accurately predict acute radiation injury to one or more organs and/or tissues of physiological systems within 4 hours of radiation exposure to allow for rapid triage in a military operational environment.

A narrative rationale and summary of results that demonstrates a comparative evaluation, establishes suitability of the best model, and provides research findings with supplemental documentation to justify selection by providing theoretical rationale and definition of the proposed model design.

2. A project plan should be drafted regarding the optimization and development, plus evaluations of merits and feasibility of the selected concept solution. Describe any intellectual property concerns to include your company's rights and ability to sell or license any intellectual property as well as your company's interest in selling or licensing the intellectual property. Include any proprietary information and limitations, if any, on sharing of animal models or testing paradigms with the government and its contractors.

PHASE II: Work in this phase represents the major research and development effort to culminate in a well-defined biodosimetry model. The principal deliverables of this phase will be complete documentation for concept demonstration of the model; statistically relevant test results, and a detailed proposal of the path forward to develop this biodosimetry triage tool. Focus on the development of rapid, reliable, inexpensive and easy-to-use techniques/assays and devices and imaging techniques to identify and characterize radiation injury to organs/tissues of physiological systems.

Milestones and deliverables for Phase II:

1. Provide documentation for concept demonstration of in vitro and/or animal model development (i.e., small animal species, large animal species, route of exposure in relation to diagnosis). Specifically, the identification, evaluation and characterization of radiation injury biomarkers based on radiation-induced gene expression, protein expression, DNA or protein modifications, metabolomic, lipidomic, immunomodulatory, cytogenetic, inflammatory, biochemical and/or physico-chemical changes predictive of early and delayed injury to organs/tissues.
2. Provide report outlining data associated with time to diagnose, specificity and sensitivity of assays, throughput, manufacturing capabilities, and special requirements of use.
3. Summarize any efforts related to manufacturing process development, to include assay qualification and validation, production qualification and validation, and process scale-up.
4. Provide an overview of accomplishments relevant to Pre-Market Approval (PMA) or 510 (k) clearance.
5. Delivery of summary documentation with supporting data for full protocol development and final written methods as study specific procedures (SSPs) or standard operating procedures (SOPs), including material handling, facilities engineering requirements, associated SOPs such as instrument calibration dosimetry validation, and all other information to perform the work as necessary.
6. Delivery of a detailed plan for technology transfer and conversion of the model into validated method; actual work to be performed in Phase III.
7. Develop and deliver projected program with schedule and cost projections for Phase II work as defined above.
8. Executive summary report and detailed cost and schedule proposal for continuation into Phase III.

PHASE III DUAL USE APPLICATIONS: Phase III will comprise the full development and validation of a biodosimetry triage tool. The system (tool, device, biomarker, or bioassay) shall be reviewed within the regulatory processes of the U.S. Food and Drug Administration's (FDA) Center for Devices and Radiologic Health (CDRH) and, any required animal studies could have added regulatory overview under either the FDA's Centers for Drug Evaluation and Research (CDER) or the Centers for Biologics Evaluation and Research (CBER). The phase will focus the regulatory path to a diagnostic's FDA Pre-market Approval (PMA) or 510(k) clearance and subsequent production of a device for biodosimetry triage in a military operational environment.

KEYWORDS: Biodosimetry, biomarkers of acute radiation syndrome, radiation exposure triage.

CBD13-109 TITLE: Closures with Hermetic Sealing for Chem Bio Protective Garments

TECHNOLOGY AREAS: Chemical/Bio Defense, Materials/Processes

OBJECTIVE: Mechanical closures of the hook and loop type used in Army uniforms are the critical sources of leaks in protective clothing/equipment, limiting the protective capability of the ensemble. To address this problem, new closure systems need to be developed to provide both the macroscopic adhesion strength obtainable from the hook and loop closures while also allowing for hermetic sealing against any vapor permeation through the closure. No existing type of closure systems can accomplish these objectives and new concepts need to be developed. This topic addresses the technical challenges and innovative solutions sought to achieve a hermetic sealing closure system for protective clothing ensemble.

DESCRIPTION: Chemical protective fabrics used in clothing are designed to be impervious to chemical and biological agents while allowing for thermal comfort to the wearer by permitting moisture transport. The chemical protective nature of the garment ensemble is however compromised by the use of conventional mechanical closure of the hook and loop type (Velcro is a commercial example), which has macroscopic contact regions through which significant gas transport is possible.

Different types and classes of hook and loop closures are used in Army uniforms and the specifications are described in the General Services Administration commercial item description A-A-55126B [1]. The typical minimum peel strength is in the range 0.5 to 1.0 lbs/inch (75 to 150 N/m). The typical lap shear strength is in the range 5 to 30 lbs/sq. inch (35 to 210 kPa). While there are other properties that can be important, this solicitation will be focused on adhesive strength as indicated above, measured by the ASTM peel strength and lap shear strength measurement methods.

One may speculate that adhesive contact surfaces with nanoscopic roughness may provide larger resistance to gas transport, compared to the hook and loop system with macroscopic roughness. Further, the possibility of generating significant adhesion between surfaces possessing nanoscale contacts has been recognized from a study of biological systems [2,3]. Based on this concept, one may consider coating polyelectrolyte multilayers on substrates since the multilayers have numerous polymer contact elements in the nanoscopic range and can provide adhesion between surfaces [4]. In a recent study the adhesion and hermetic sealing of such a multilayer closure was investigated [5]. This study showed that the resistance to air flow through the multilayer closure system is approximately 20-800 times larger than that possible with conventional hook and loop type closure systems, at all humidity levels (from 5 to 95% relative humidity), as measured by the Dynamic Moisture Permeation Cell (DMPC) apparatus [6]. However the adhesive strengths of the polyelectrolyte multilayer closure systems evaluated in this study are an order of magnitude smaller than the hook and loop closure and therefore the multilayer system as developed cannot be employed for closure application.

As shown in these studies, new closure concepts are possible and they are the focus of this topic. Some obvious approaches built on the work described here are as follows: One option is to develop polymer systems that can provide significantly large adhesive energies while maintaining hermetic sealing. One recent study shows that moisture retention in the multilayers leads to significant increase in the lap shear strength [7]. Another approach to achieving large adhesive strength based on surface patterning has recently been proposed, inspired by biomimetics [8, 9]. Another option is to use the hook and loop system for providing the adhesion strength and integrate it with another system such as the multilayer to achieve hermetic sealing. Entirely new approaches can be considered as well.

PHASE I: Conduct research on novel concepts for closure system to achieve both hermetic sealing and minimum adhesion strength needed. Upon completion of Phase I, samples of the closure system developed on any flexible substrate should be made available for independent evaluation. The system should show peel strength and lap shear strength in the range specified under Description and an air flow resistance at least 100 times larger than that from the typical hook and loop system (with their backs sealed to prevent air leakage) over the humidity range of 5 to 95% RH, as measured by the DMPC. The hook and loop system for the comparative study will be identified by the Technical POC.

PHASE II: The closure system developed should be integrated with a fabric such as NYCO. It should be possible to produce the integrated closure system in large scale. At the end of Phase II, closure samples on a swatch of fabric should be made available for independent evaluation. The closure samples should provide the adhesion strength and air flow resistance specified under Phase I goals over the entire relative humidity range and these properties must be retained after laundering at least 3 times under military laundering conditions.

PHASE III: A closure system demonstrated in Phase II successfully should be integrated into chemical and biological protective clothing ensemble.

PHASE III DUAL USE APPLICATIONS: First responder and anti-terrorism personnel would also benefit from use of improved protective garments providing hermetic sealing. In addition to protective clothing, other applications such as for respirator face seals, vehicle doors and windows, and attachment of tent and other shelter modules are possible. Further, the closure can be used for applications such as face masks in hospitals, schools, and other buildings when high levels of protection from indoor contaminated air are desired.

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KEYWORDS: closures, fasteners, hermetic sealing, airflow resistance, peel strength, lap shear strength

CBD13-110 TITLE: Self-Healing Shape Memory Polymer Coatings for Chemical/Biological Protective Clothing

TECHNOLOGY AREAS: Chemical/Bio Defense, Materials/Processes

OBJECTIVE: To develop and prepare self-healing shape memory polymer coatings which contain embedded nano-capsules of bi-component reactive chemicals for use in Chemical/Biological (CB) protective clothing.

DESCRIPTION: Soldiers' personal safety is compromised when CB protective uniforms become torn. This topic seeks to develop coatings to self-seal or heal a textile material. Technology applications include enhancing fielded uniforms such as the Joint Service Lightweight Integrated Suit Technology (JSLIST) and the Uniform Integrated Protective Ensemble (UIPE) future increments as well as multiple individual clothing and equipment (CIE) items. There are two known approaches for in situ clothing repair: (1) Interaction of reactive chemical species encapsulated in nano-capsules which are pre-embedded in the coating, and (2) Application of an external force (e.g., increased temperature and/or pressure, etc.) to torn clothing as in a simple laundering procedure for supramolecular polymer coatings. [Reference 1] This topic will focus on the first approach, and solicits technical efforts to develop solutions to self-seal the tears on soldier's clothing. This topic is also open to other novel solutions addressing the technical innovation sought. Past work on self-healing polymers has shown that it is possible to produce microcapsules (10 to 100 micrometers) containing reactive chemicals for use in self healing polymer systems; [References 2 to 5] however long term stability of the catalyst is a possible issue, and micro-size capsules (50 micrometers plus) are not suitable for coating applications. [Reference 1] In more recent studies, nanocapsules (100-500 nanometers) were found to provide sufficient interfacial area when incorporated into a polymer coating to significantly improve self-sealing efficiency. [Reference 6] Furthermore, self-healing epoxy coatings, with two compartmentalized reactive species (a modified amine and epoxy, respectively) embedded within the coating was demonstrated. [Reference 7] The two reactive species were encapsulated prior to being embedded in the polymer coating using emulsion polymerization.

Shape Memory Polymer (SMP) [Reference 8] materials are another complementary approach to past self-healing systems by functioning as responsive matrix carrier for the bi-component reactive nano-embedded capsules. This is due to the matrix ability to adjust its molecular structure to restore (i.e., remember) a polymer coating to the original state (prior to the damage event) thus minimizing flaws such as torn gaps.

Coatings should have comparable physical characteristics as that of virgin (un-torn) polymer coatings after the self healing process occurs. They should not adversely affect the performance of the protective ensemble. The following are selected key performance goals/metrics for coating applied to textile materials and protective clothing.

- Tensile/Tear Strength (FTMS191A TM5034; at break): Warp: > 200 lb; fill: > 125 lb; Elongation > 35%.
- Abrasion Resistance (FTMS191A TM3884): > 5000 cycles.
- Stiffness (FTMS191A TM5202): < 0.01 lb.
- Dimensional Stability (FTMS191A TM2646): Unidirectional Shrinkage < 3%.
- Durability (FTMS191A TM 2724): Pass after 5 laundering cycles without tear gap(s) reopening.
- Weight (FTMS191A TM 5041): < 0.1 oz/sq. yd of added weight to the self-healed area.
- Thickness (FTMS191A TM 5030): < 25 µm (micrometers) of added thickness to the self-healed polymer.
- Colorfastness (FTMS191A TM5605): Minimal to no visual (color) changes to self-healed tears.
- Air Permeability (FTMS191A TM5450): < 0.2 cu. ft of air/min./sq. ft (i.e., minimal to no significant changes.)
- Chemical Warfare Agent (CWA) simulant permeation resistance (NSRDEC In-house test method): < 10 g/sq. m/24 h.

PHASE I: Develop a series of self healing coating materials to demonstrate feasibility. Identify successful candidates using methodology described in the key performance goals. Analyses shall include parameters listed above. Successful coatings shall have comparable characteristics of base polymer coating (i.e., flexible, and durable, etc.), and will not degrade the current performance metrics of fielded clothing systems, and be feasible for application to clothing/textile in Phase II. Key physical properties such as tear resistance and CWA simulant permeation data will be used as the primary decision criteria for Phase II work continuation.

Phase I deliverables: Self-healable SMP coating samples on release glass surface or standalone films, and a technical report documenting concept design, processes and equipment and test data analysis approaches used in the development of novel coatings, as well as literature searches, technical processes, equipment, materials and chemicals used, technical references, etc. (TRL 4 Component and/or breadboard validation in laboratory environment.)

PHASE II: Refine self healable SMP coating formulations, produce durable coated textiles, and refine pilot and commercial processes to produce defect-free coated textiles. Key performance metrics identified in the Description section will apply in Phase II. Prototype clothing will be fabricated, and system level testing will be conducted to assess the usability of self-healing textiles. A commercial viability study will be conducted, and commercial partners identified for Phase III. System level testing will include laundering, thermal manikin testing, rain-room testing, etc. Limited field durability testing of self-healing SMP coated clothing will be planned and conducted under NSRDEC guidance. Life cycle and environmental testing of self healing SMP coated clothing will be conducted. Material costs and cost metrics of viable commercialization of self-healing SMP coating technology will be assessed and studied.

Deliverables: 100 linear yards of self-healing SMP engineered fabric, and a final test report will be submitted which includes details of the down-selection process of self-healing SMP coatings, technical data, test results of material and system-level testing, evaluation of coated clothing, technical processes for producing novel coatings and coated textiles, commercial viability study, cost metrics, and life cycle and environmental test results. (TRL 5 - Component and/or breadboard validation in relevant environment.)

PHASE III: Transition new self-healing coated textile technology to fielded applications such as the All-Purpose Personal Protective Ensemble (AP-PPE), the Joint Chemical Biological Coverall for Combat Vehicle Crewman (JC3), the Integrated Footwear System (IFS) sock, and the JSLIST Overgarment, and dual-use applications such as clothing for chemical handlers, agricultural workers, domestic preparedness emergency responders, anti-terrorism personnel, and medical personnel working in potentially contaminated environment with toxic industrial chemicals and bacterial/viral infected environment. Self-healing shape memory polymer coated textiles will also be ready for transition to the next UIPE increment. (TRL 6 - System/Subsystem model or prototype demonstration in a relevant environment.)

PHASE III DUAL USE APPLICATIONS: SBIR contractor and its commercial partners will formalize partnerships and actively seek dual-use applications for novel self-healing SMP coated textiles and protective clothing. Potential

applications include commercial clothing for mountaineers, all-weather sport enthusiasts, as well as non-clothing applications.

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Cited materials are readily accessible and available as referenced above.

KEYWORDS: self healing, self-sealing, self repairing polymer/coating/textile, shape memory polymer coating/film shape memory polyurethane, bi-component reactive materials, microencapsulated particles.